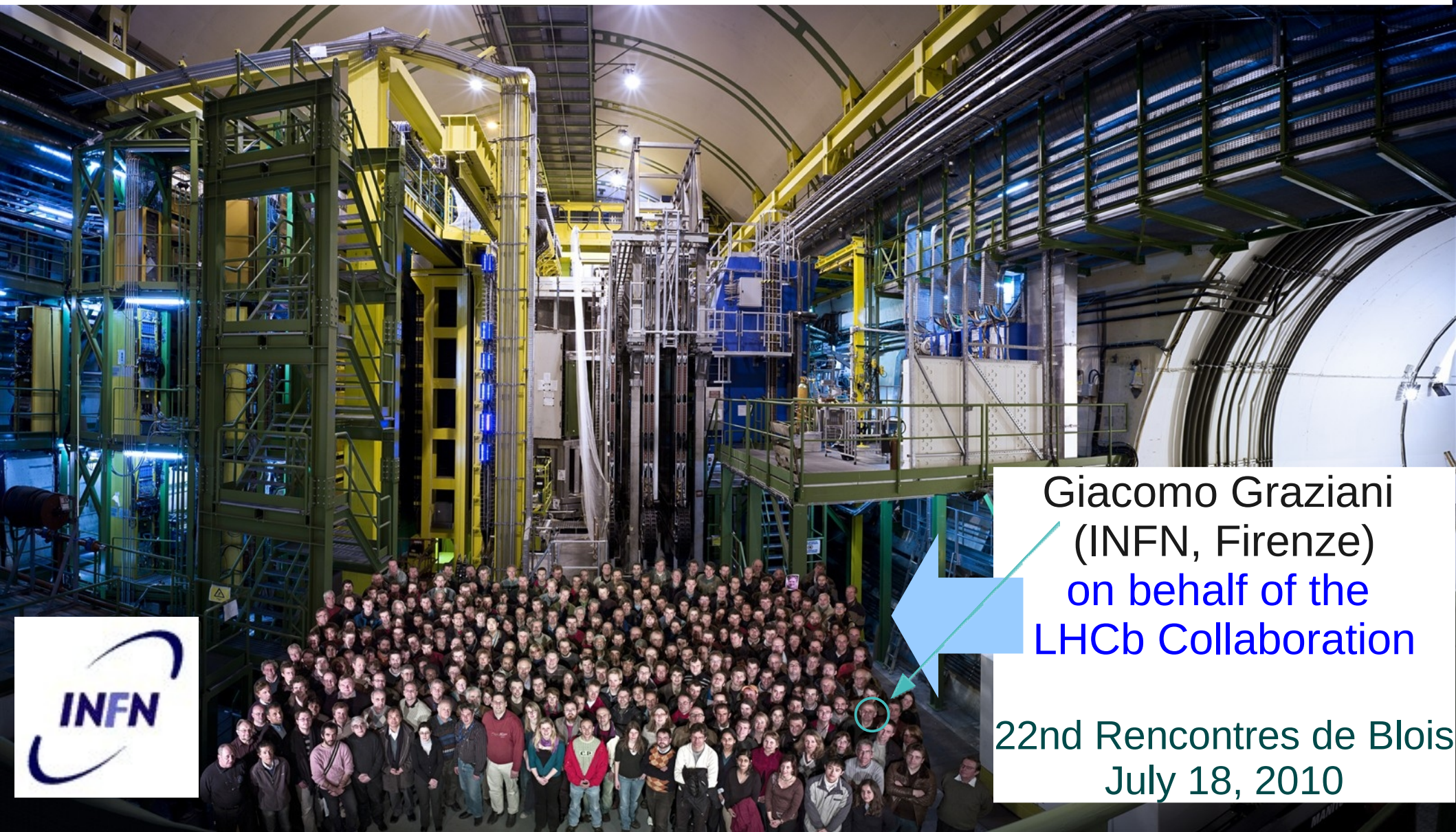
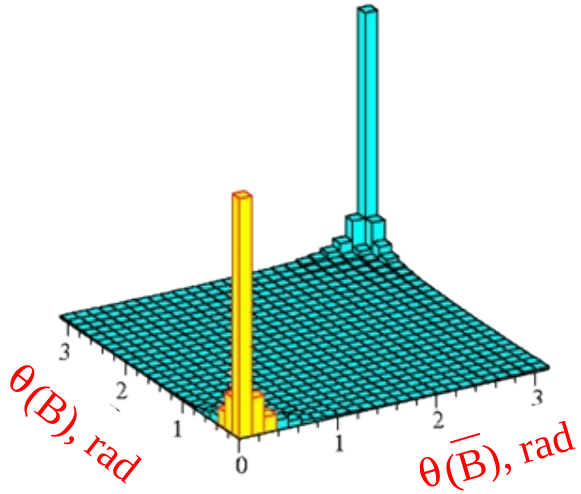
Detector Commissioning with First Data



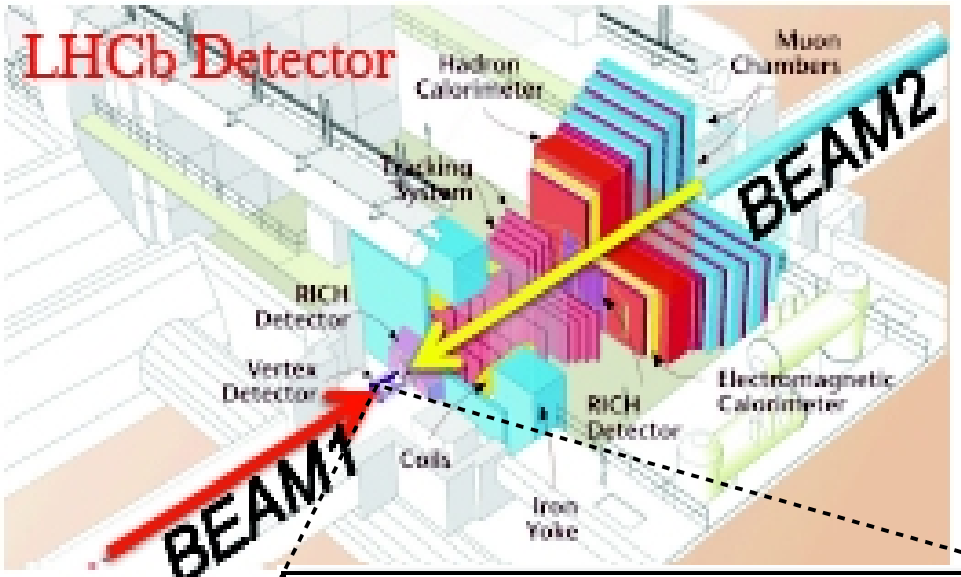
Giacomo Graziani
(INFN, Firenze)
on behalf of the
LHCb Collaboration

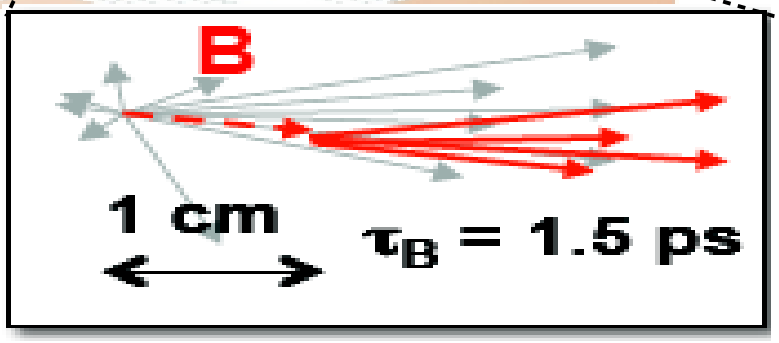
22nd Rencontres de Blois
July 18, 2010

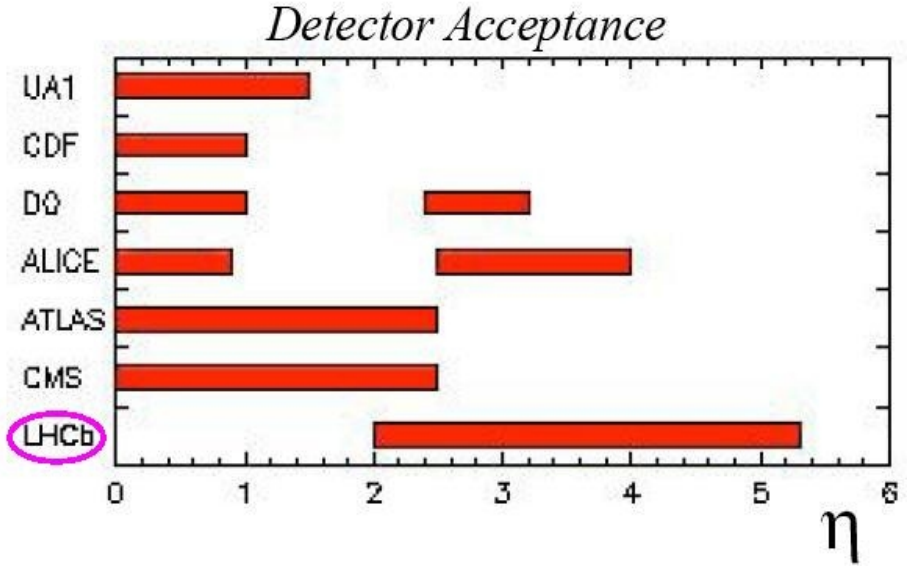
The LHCb Experiment



- Exploiting the abundant $b\bar{b}$ (and charm) production at LHC for searching new physics in the flavour sector
- Single arm spectrometer covering only the high rapidity region
- Emphasis on:
  - Vertexing, proper time resolution
  - Tracking efficiency, p resolution
  - Particle ID
  - Fast and highly selective trigger







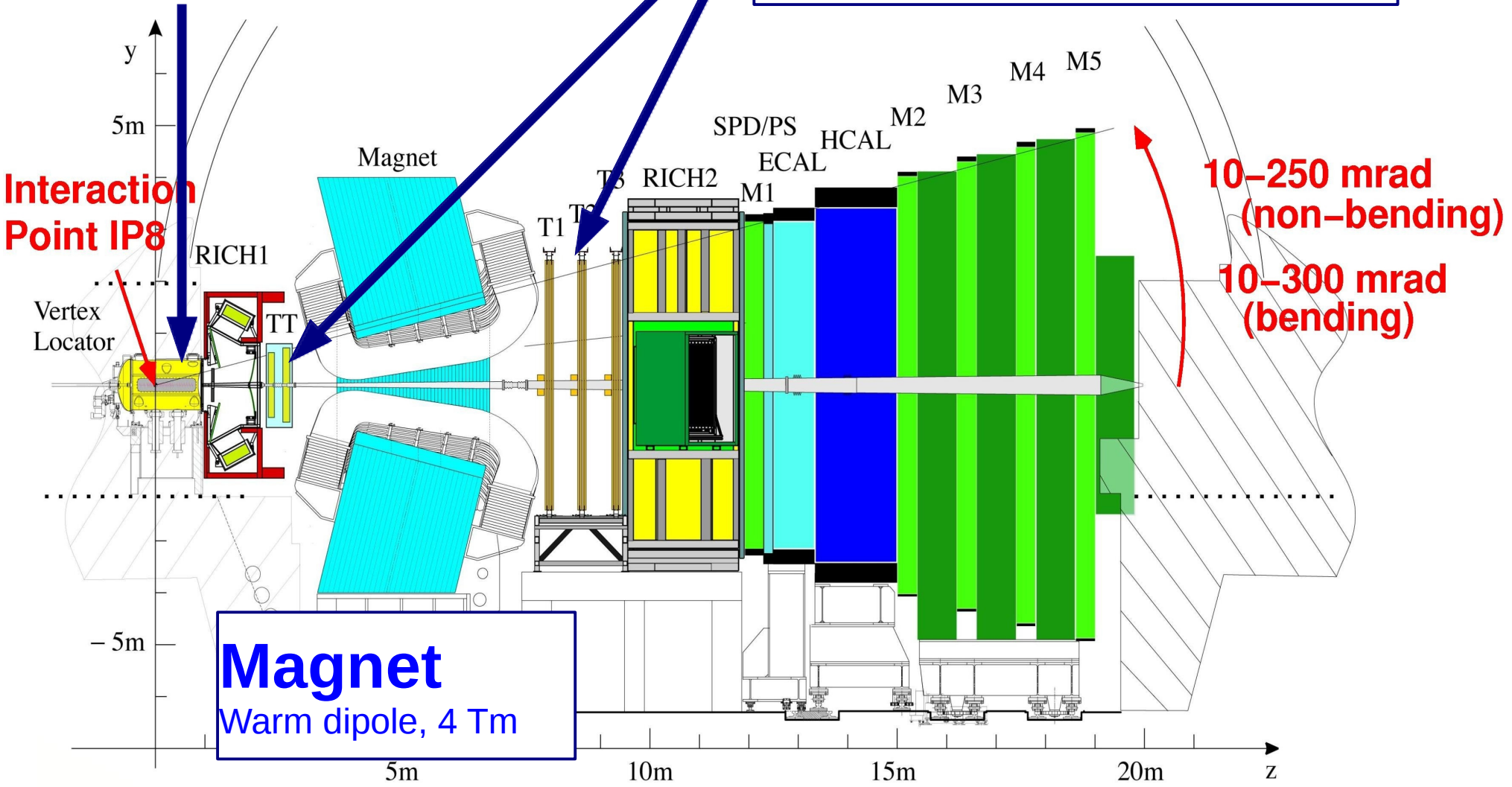
The Detector: Tracking

Vertex Locator

Si μ-strips sensors, orthogonal to beam, rφ geometry, movable device from 30 to 8 mm from beam!

Tracking Stations

Si detector for upstream and inner parts (ST), straw tubes for outer part (OT)



Magnet

Warm dipole, 4 Tm

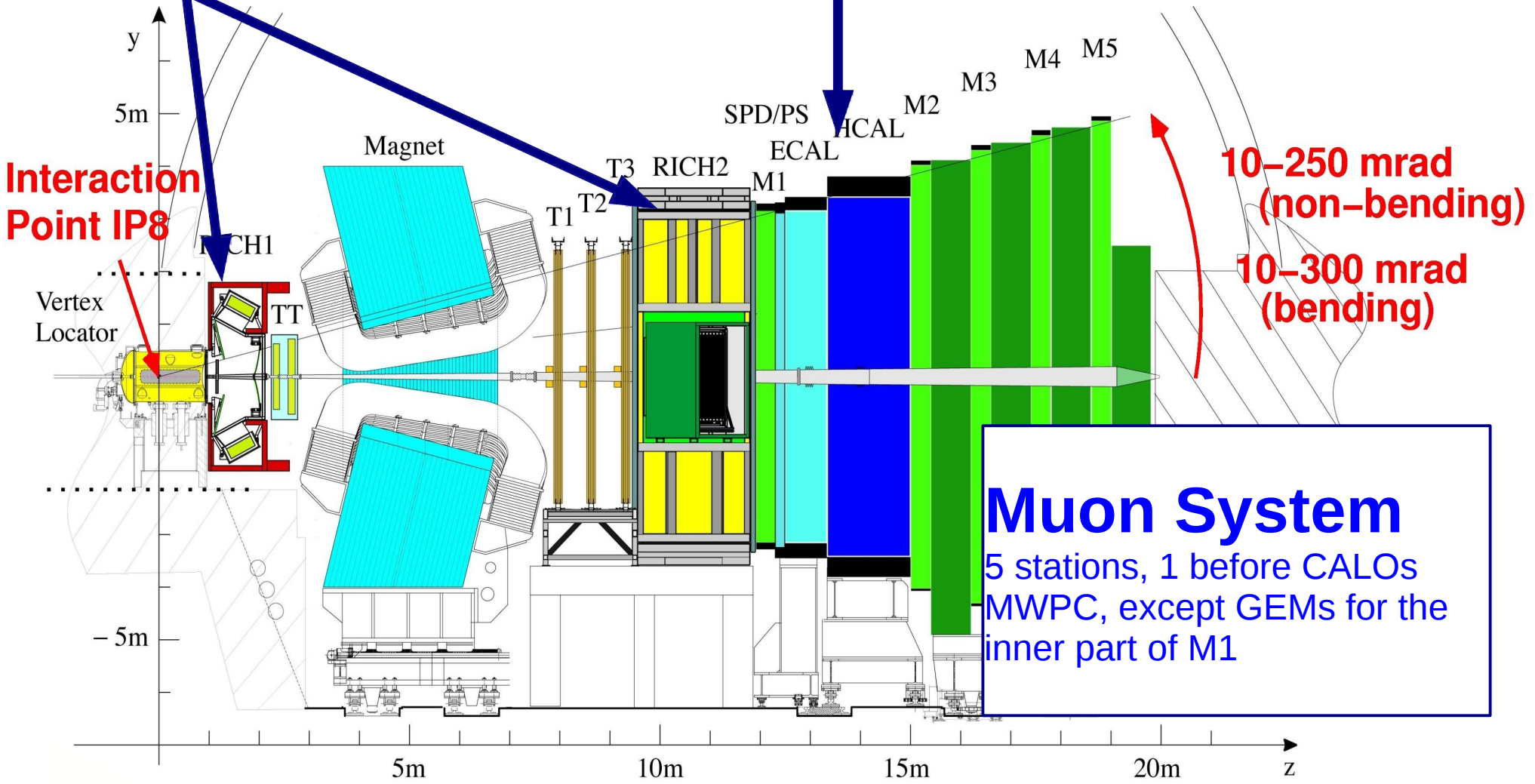
The Detector: Particle ID

RICHs

2 detectors using 3 radiators for pi/K separarton in wide momentum range (1-100 GeV).
Readout by custom HPDs

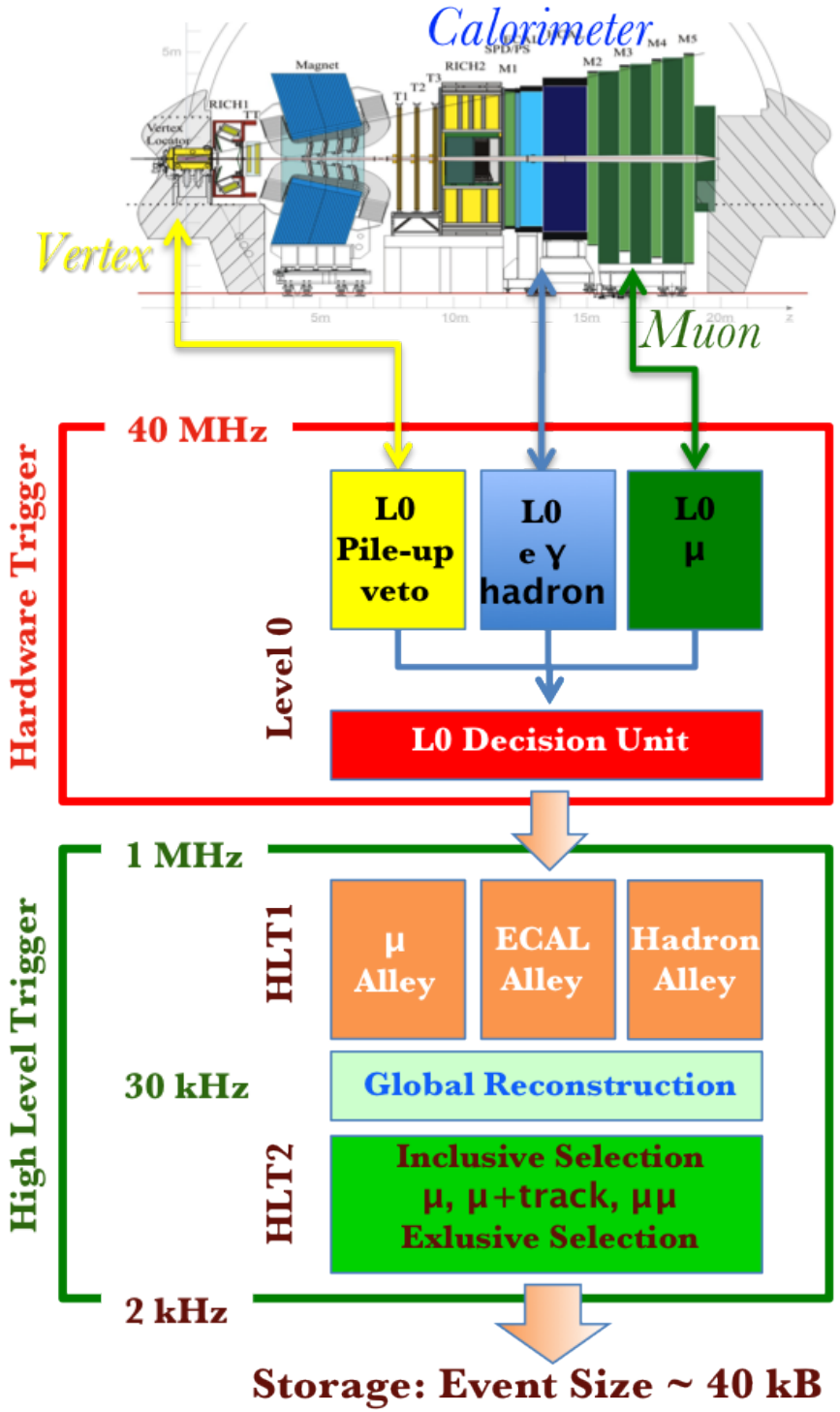
Calorimeter System

Scintillating Pad Detector,
PreShower (Pb/scint.),
ECAL (Shashlik),
HCAL (Fe/scint. tiles)



Muon System

5 stations, 1 before CALOs
MWPC, except GEMs for the inner part of M1



The Trigger

- L0 Trigger (hardware)
  - Muon detector:
    - "high"(>1 GeV) p_T muon
  - Calorimeters:
    - high p_T hadron, electron, γ
  - Pile-up Veto (select single collisions)
- High Level Trigger (software)
  - Running on computer farm
  - Add vertexing to confirm L0 candidates, perform full reconstruction
  - 2 kHz output to storage

Commissioning Step 0: Test Pulses

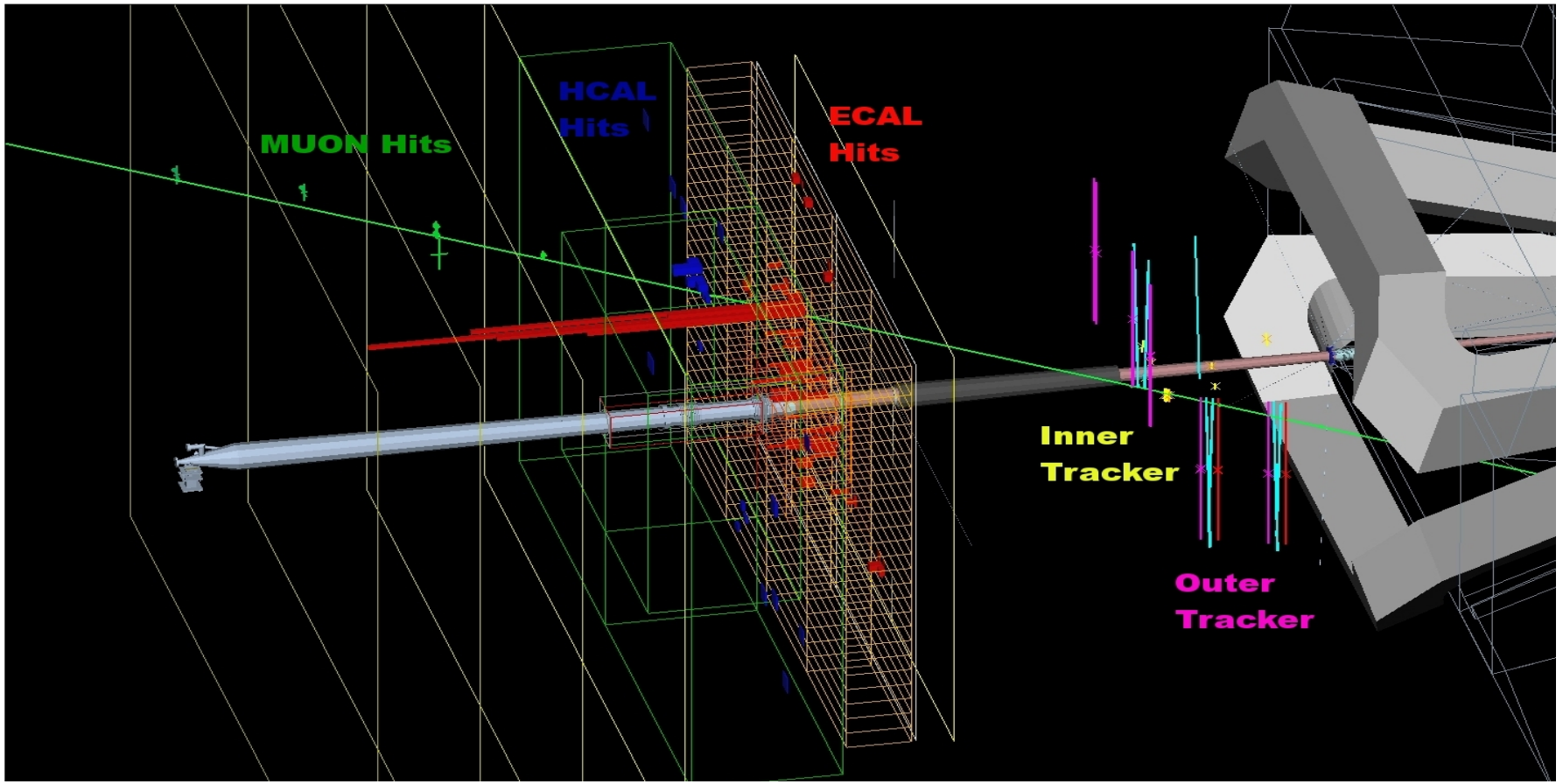
- Detector installation completed in 2008, except first MUON station (installed in 2009)
- First optical space alignment of detectors (survey)
- All detectors channels verified and first time alignment performed with pulsers or embedded test devices (LEDs for calorimeters, Lasers for RICHs,...)
- Most problems fixed during commissioning, negligible number of residual dead channels

Detector	Number of channels	Fraction of working channels
VELO	172k	99.3%
ST	272k	99.2%
OT	54k	99.7%
RICH	496k	(*) 96.7%
CALO	20k	99.9%
MUON	122k	99.8%

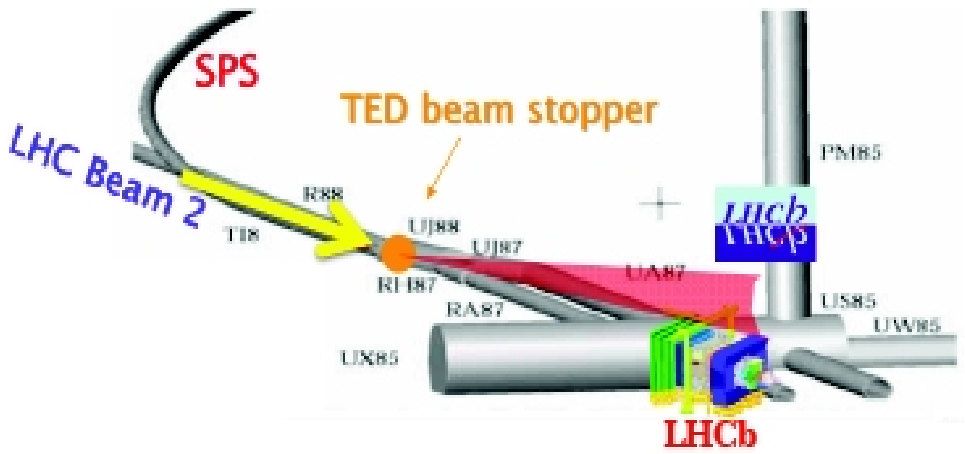
(*) some missing HPDs in border regions, with negligible effect on physics performance

Comissioning Step 1: Cosmics

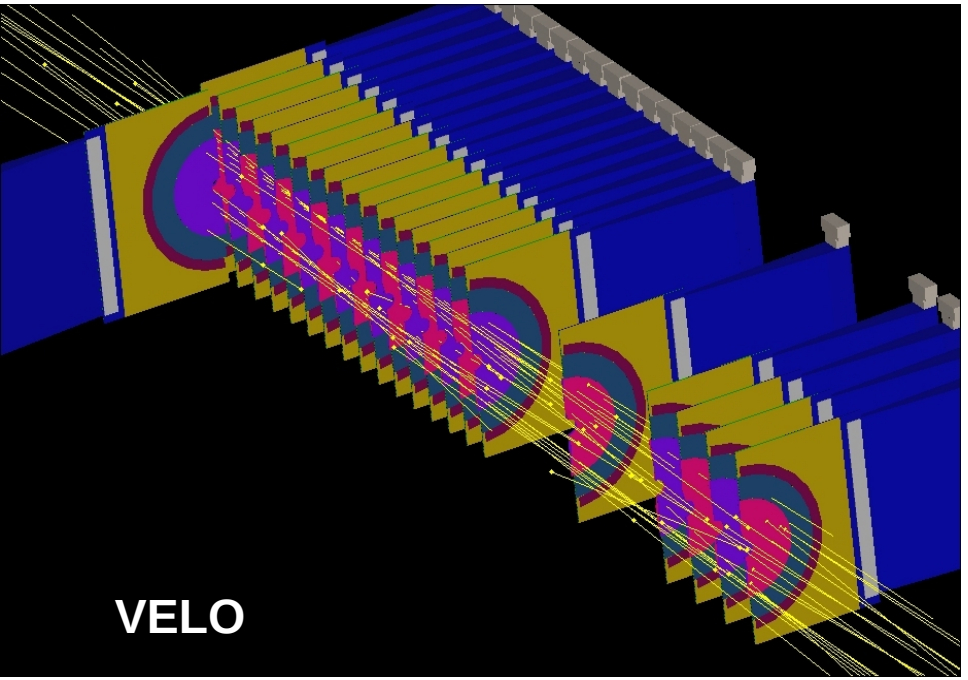
- Very low rate of horizontal cosmic tracks (~ 1 Hz crossing OT, CALO and MUON)
- But time was enough... 4Mtracks collected with CALO trigger
- VERY useful for first space and time alignment of OT, CALO and MUON => start commissioning of L0 trigger!

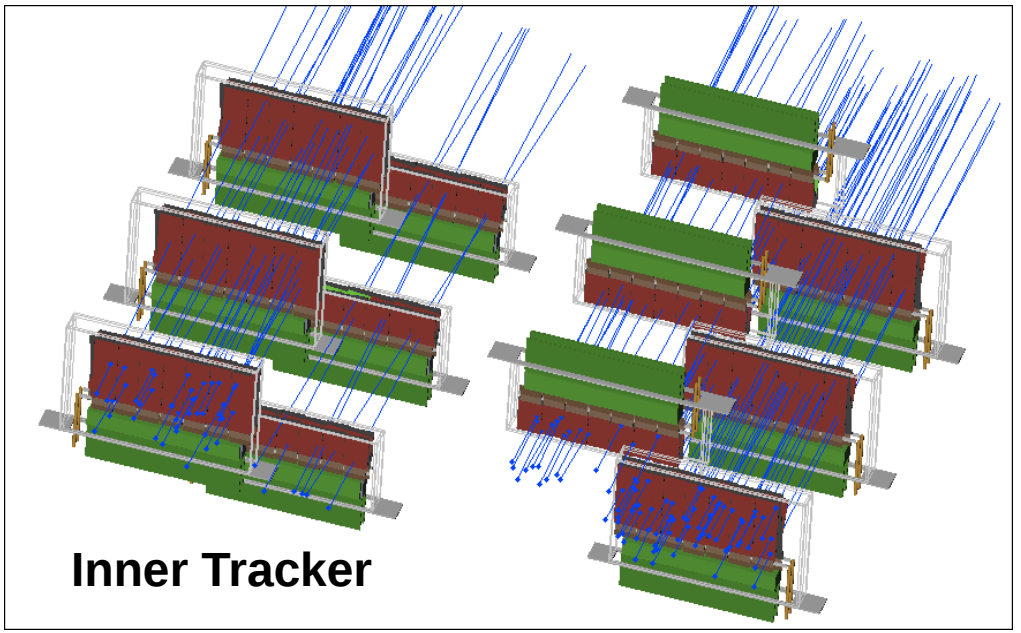


Commissioning Step 2:First LHC beams



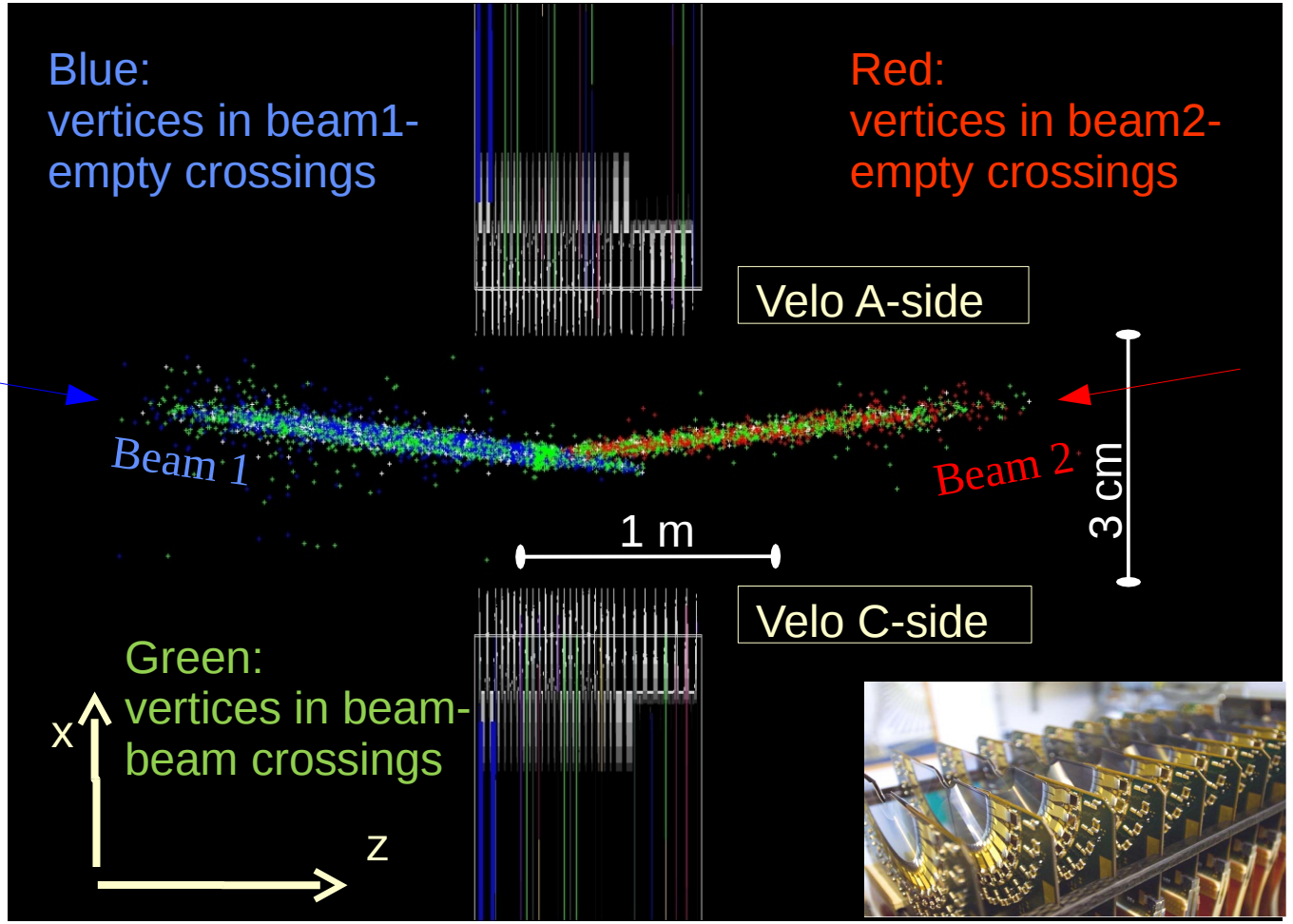
- High density (up to 10/cm^2) muon “shots” from beam dumping during injection tests
- First beam tracks seen in VELO and ST !
- Improve VELO/ST alignment with respect to survey
- Use also beam-gas collisions from first circulating beams





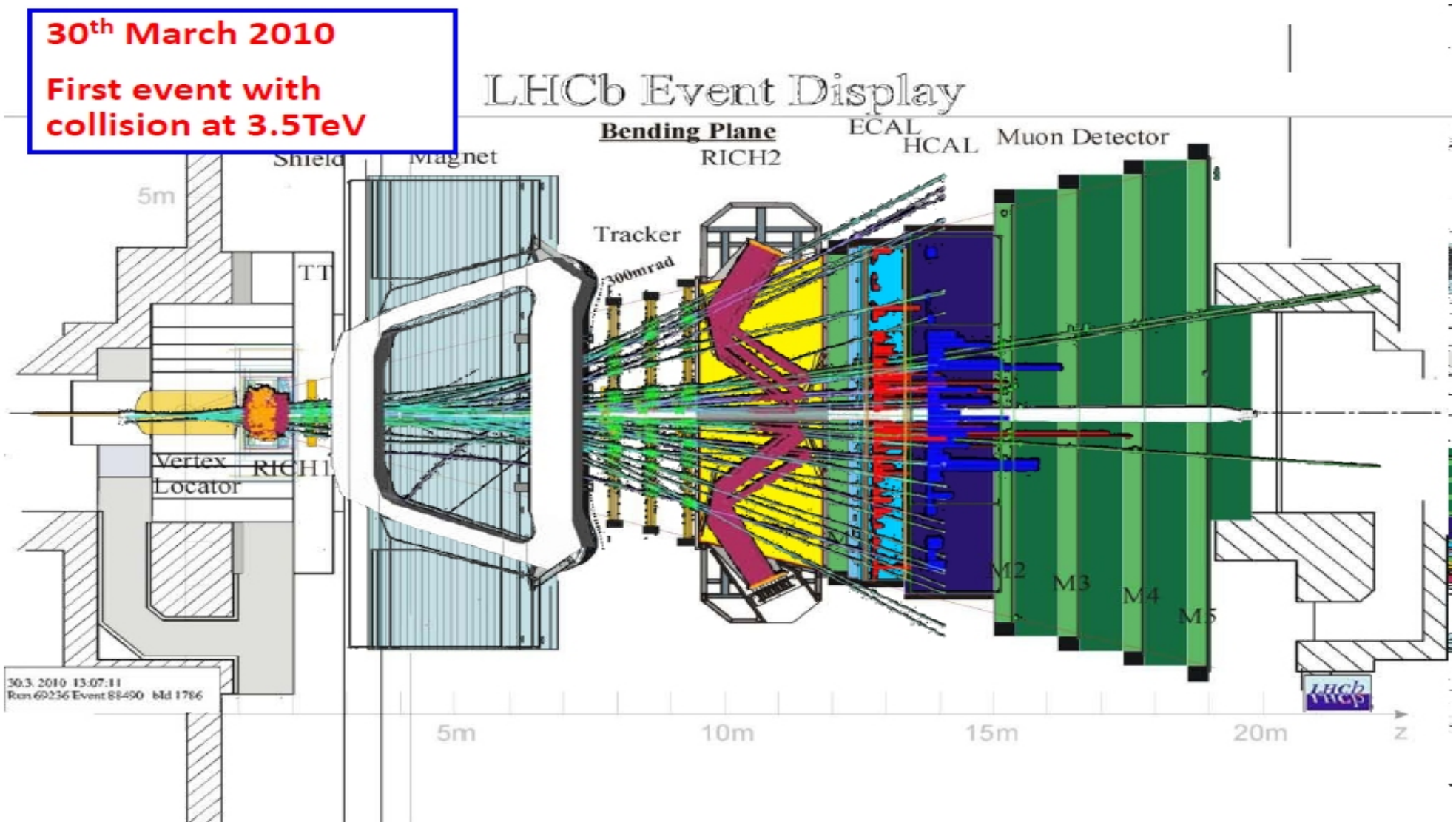
Commissioning Final Step:Collisions

- **RUN 2009**
  - VELO not fully closed (due to beam optics at 450 GeV), but could reconstruct vertexes with lower resolution



  - Use 2009 data (limited statistics) to refine alignments and calibrations

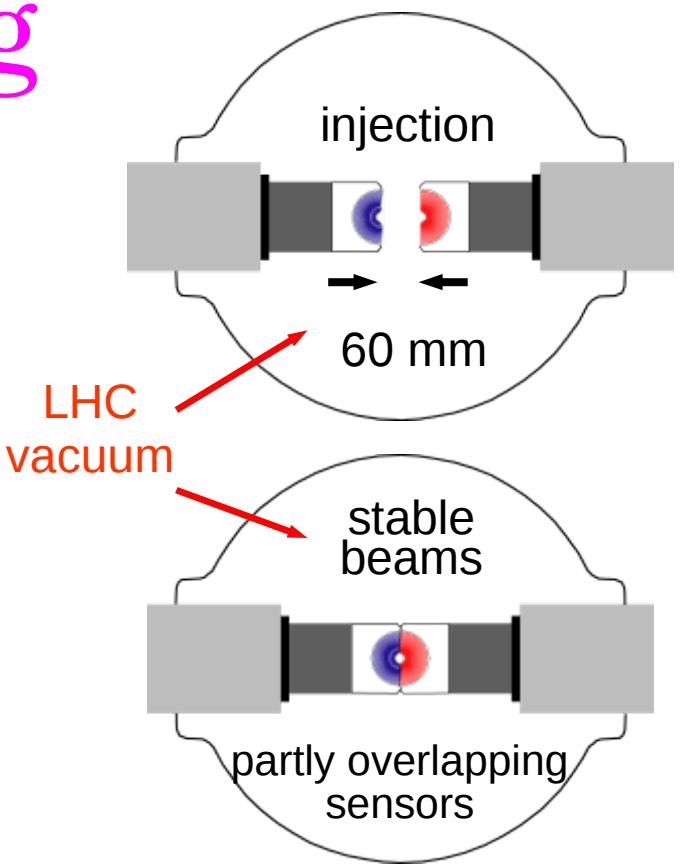
- **RUN 2010**

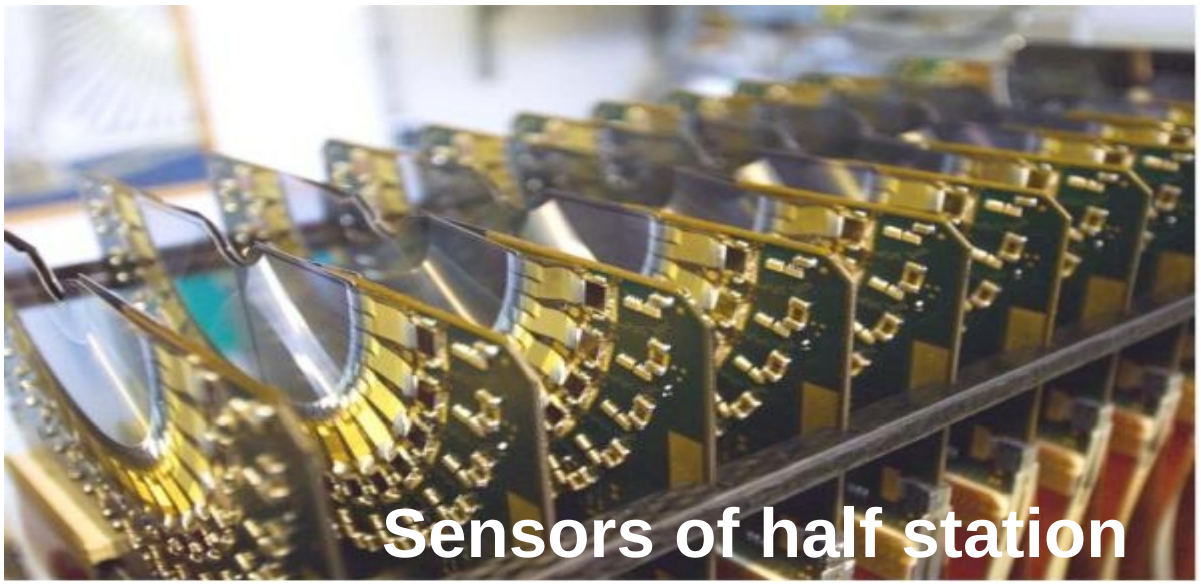


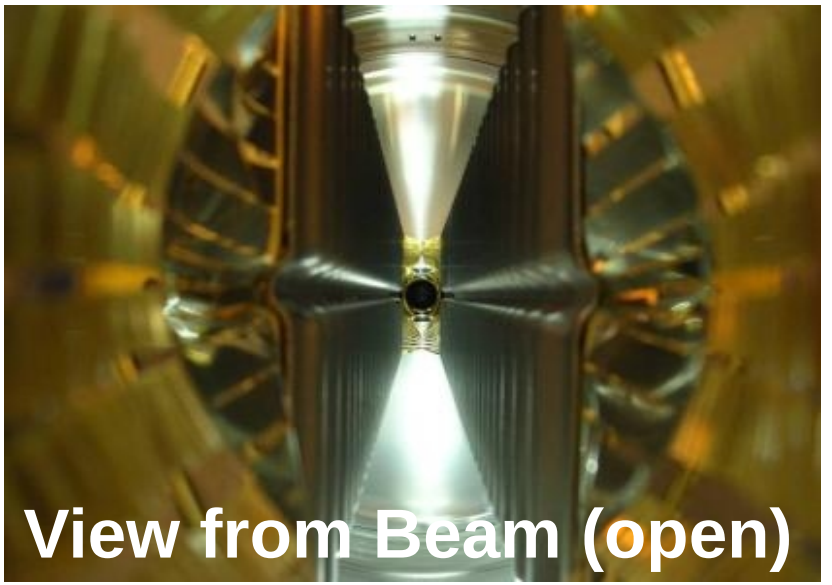
- Detector ready for physics on the first day
- Redescovery of all resosances (V0s, D mesons, Bd, Bs) as soon as luminosity allowing it

VELO closing

- VELO fully closed for the first time on April 1, 2010, after declaration of first fill with stable 3.5 TeV beams
- Operation took 2 hours...
- Now done routinely in 6 minutes, still always under VELO expert supervision

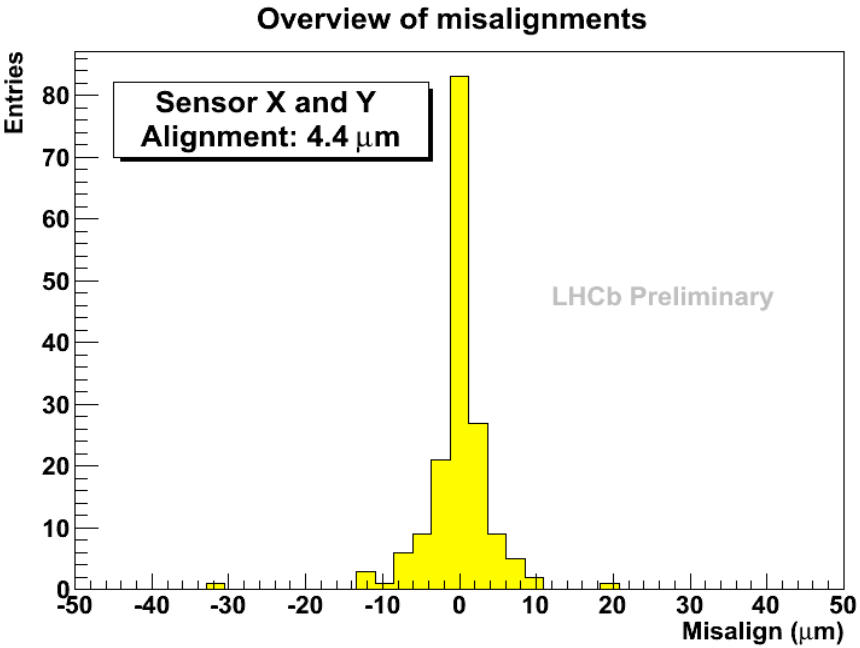


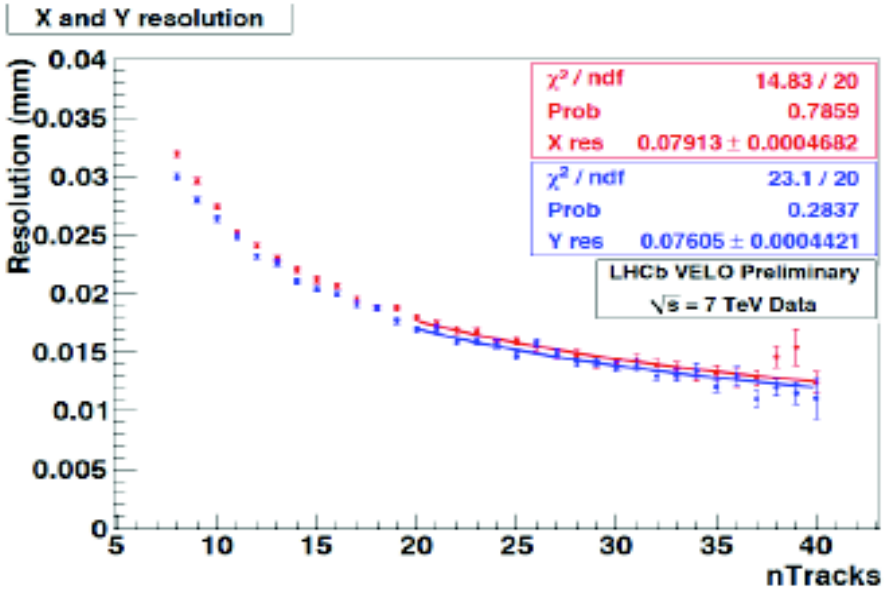

Sensors of half station

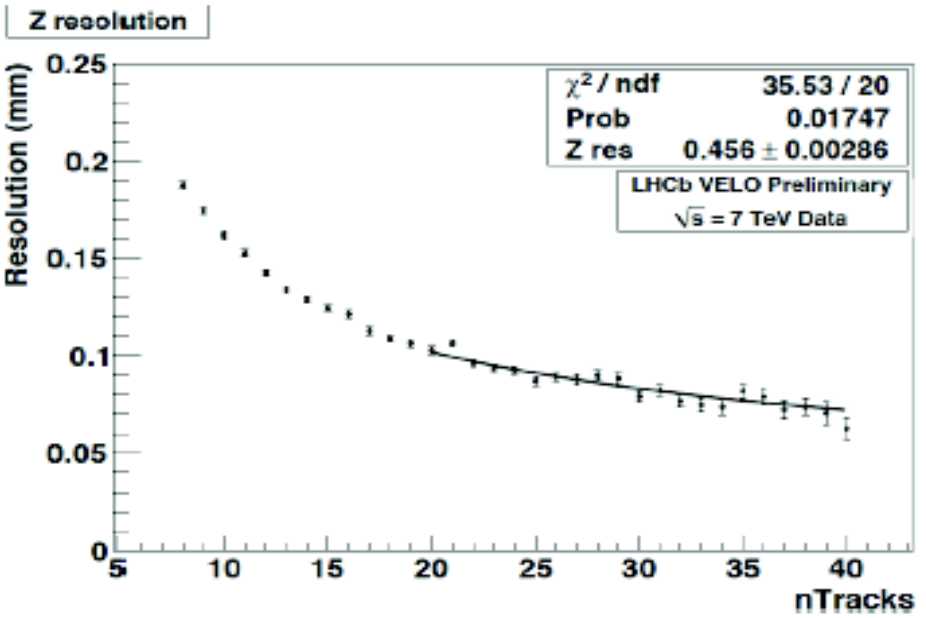

View from Beam (open)

Vertexing

- Performing full sensor alignment using the first large sample of VELO tracks, reached 4 μm residual rms
- Vertex resolution measured by random splitting primary tracks in two halves and comparing vertexes with same multiplicity. For average vertex (25 tracks) σ = 15 μm (X,Y), 95 μm (Z)
- Still 30 % worse than in MC, alignment to be finalized

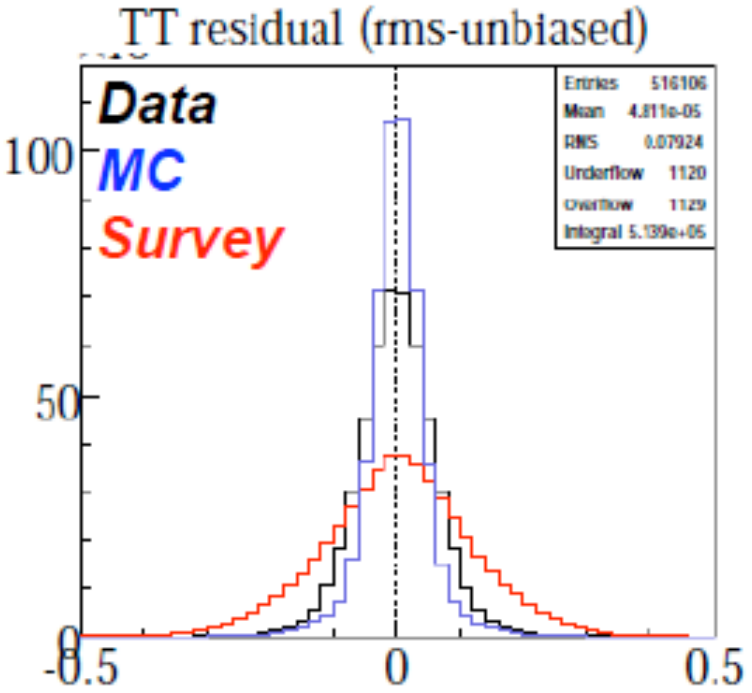


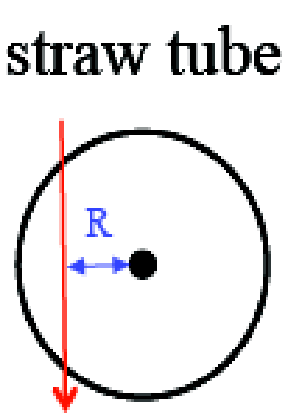


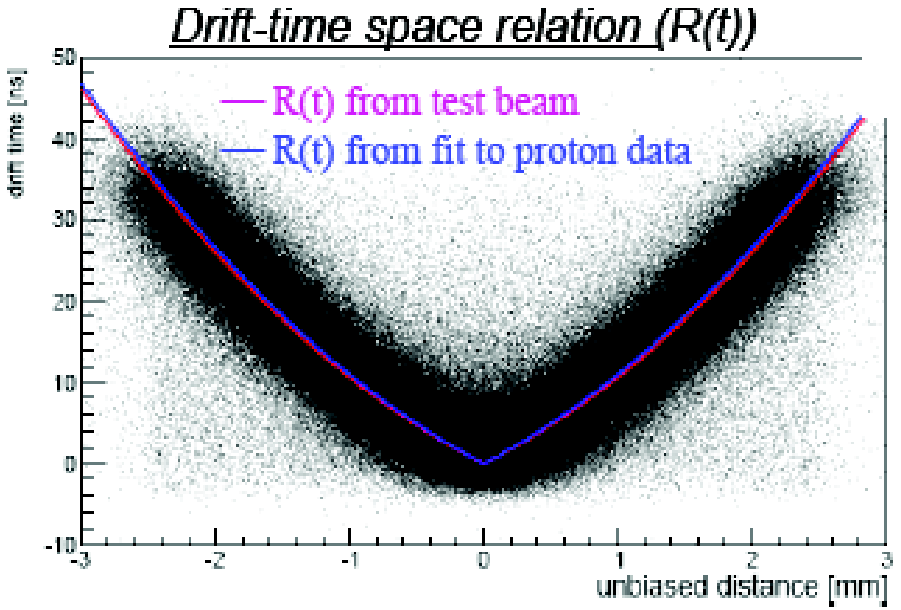


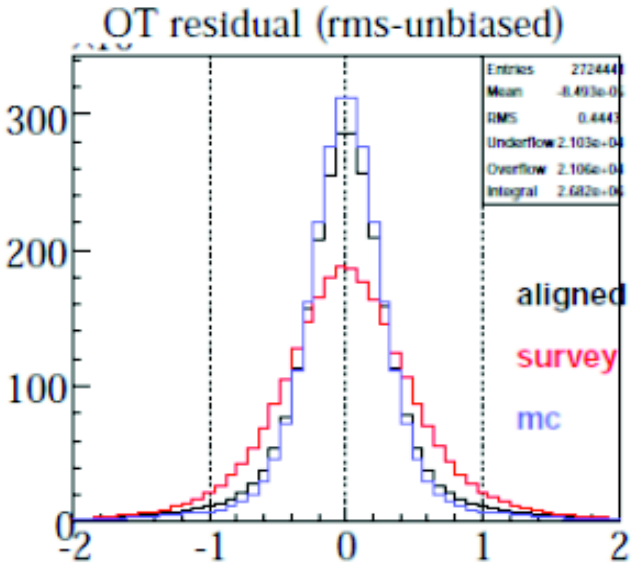
Tracking

- ST: residual rms ~ 65 μm
  - Discrepancy with MC (50 μm) understood: residual misalignment + charge sharing effect overestimated in MC
- OT: residual rms ~ 270 μm
  - drift time calibration verified
  - good agreement with simulation



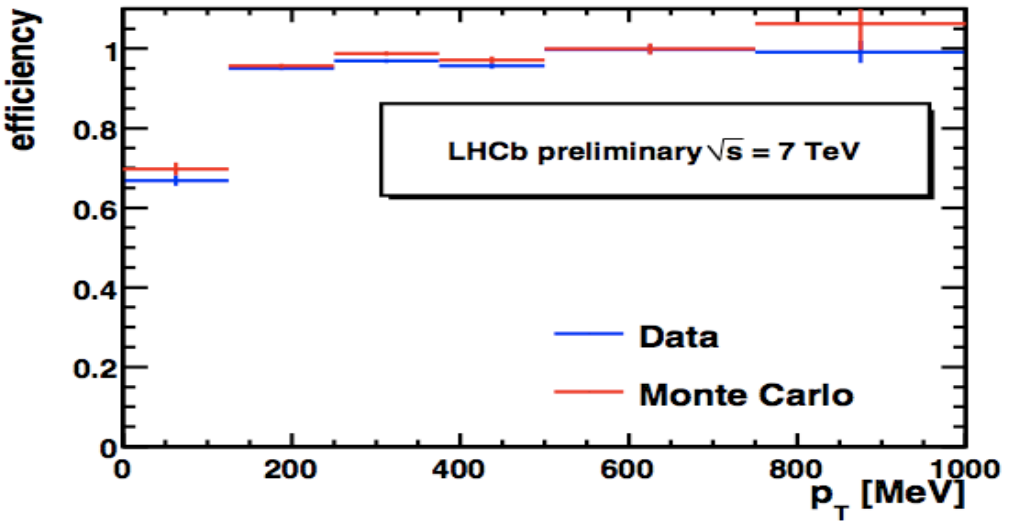


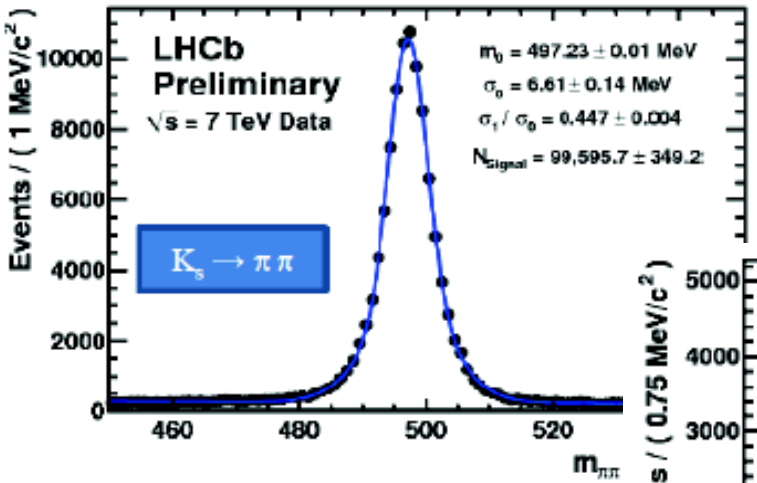


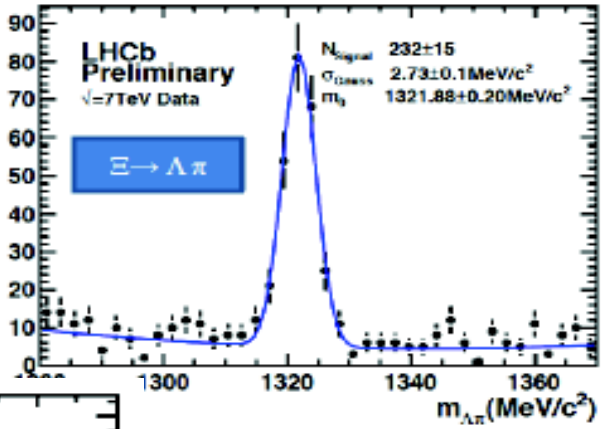


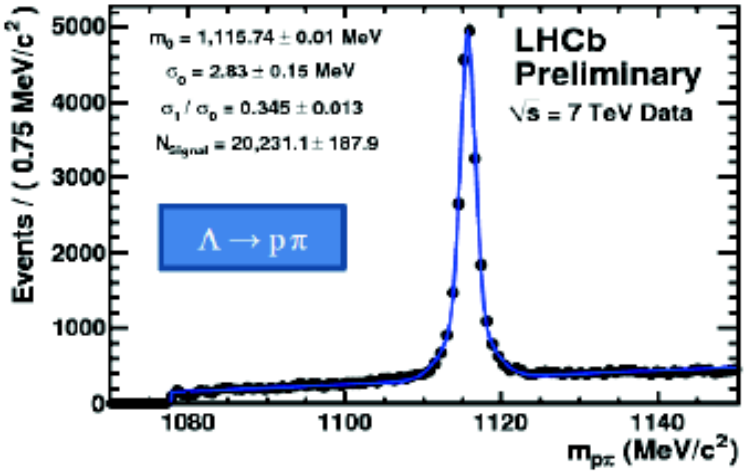
Tracking Performances

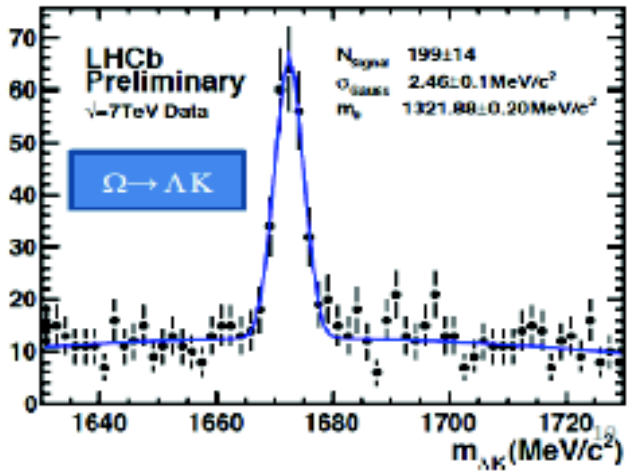
- Efficiency of tracking stations measured from K_s candidates in VELO+CALO. In agreement with expectations
- Mass resolutions also compatible, or slightly worse, than simulation



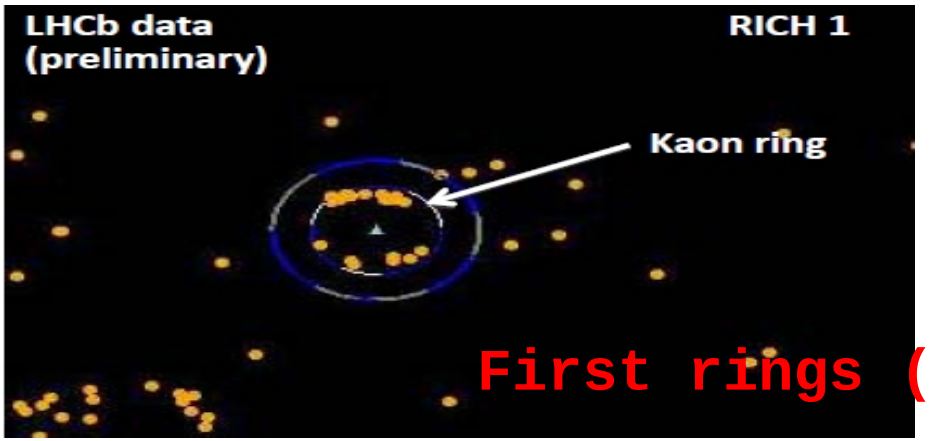


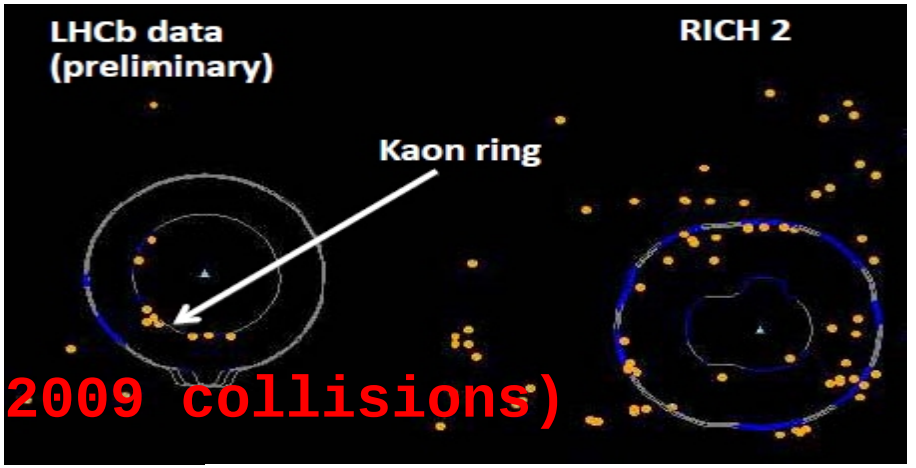






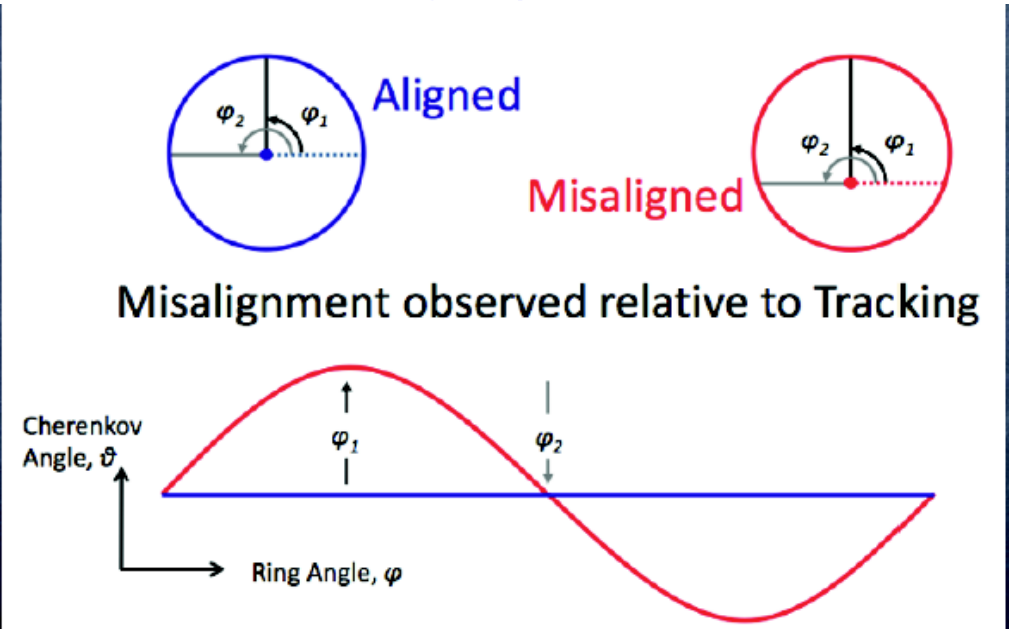
RICHs

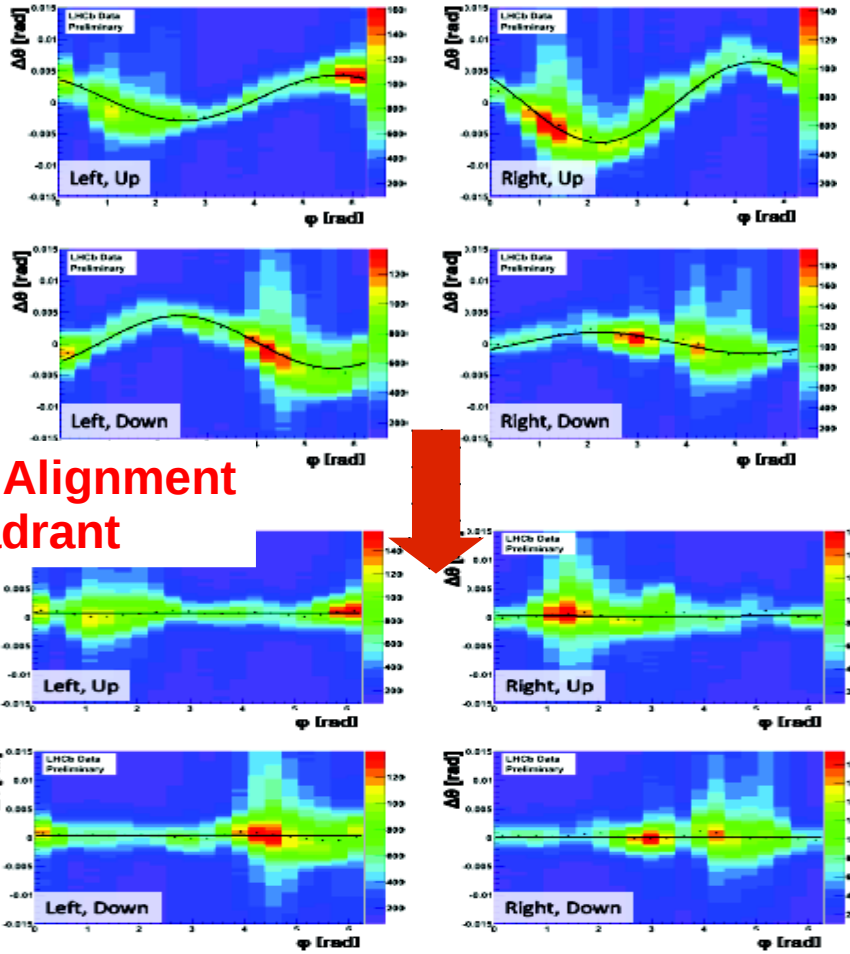




First rings (2009 collisions)

Mirror alignment performed making Cerenkov angle independent on the azimuthal angle φ





RICH1 Alignment by quadrant

RICH performances

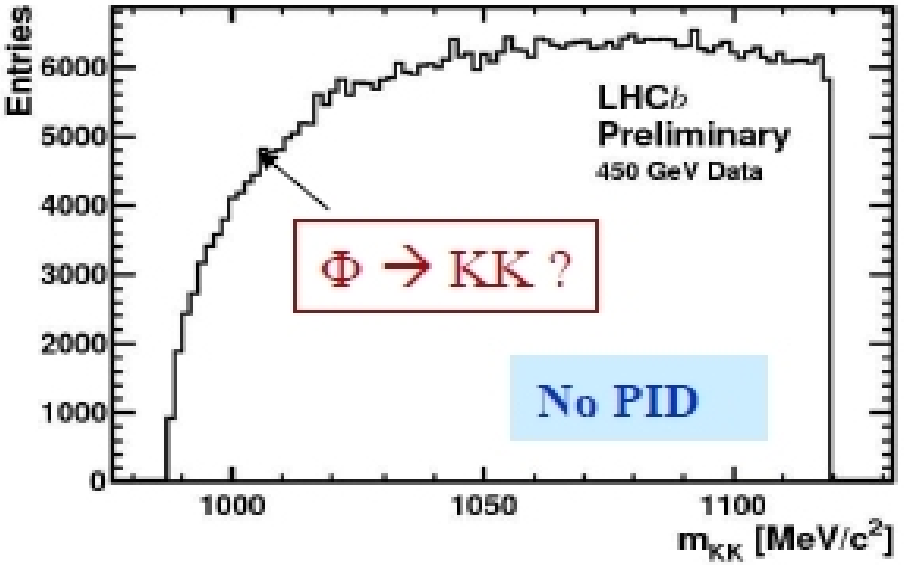
- Current resolution on Cerenkov angle θ:

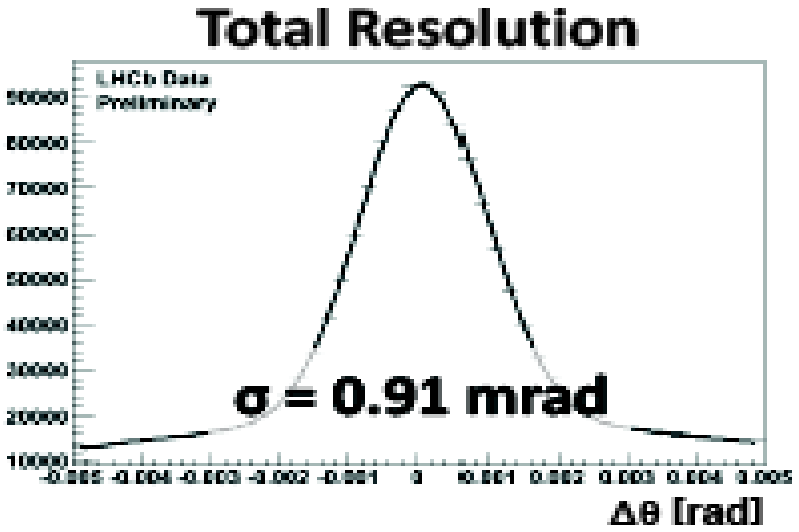
  RICH1 2.2 mrad

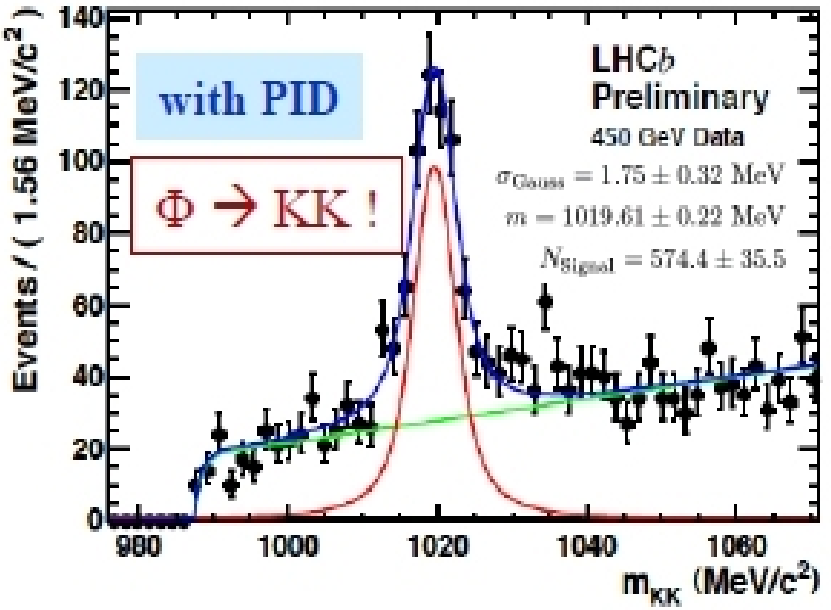
  RICH2 0.9 mrad

- Expect improvement by 20-30 % from alignment of individual HPDs and mirrors

Proof: $\Phi \rightarrow K^+K^-$

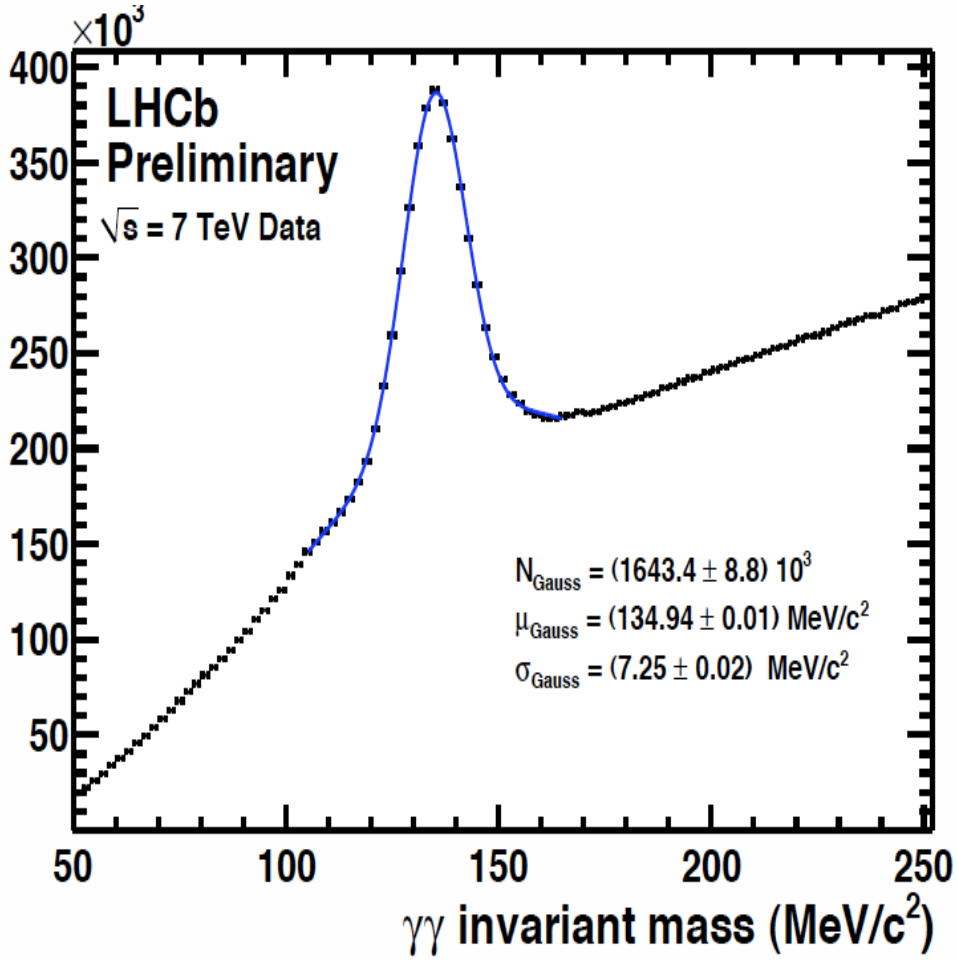


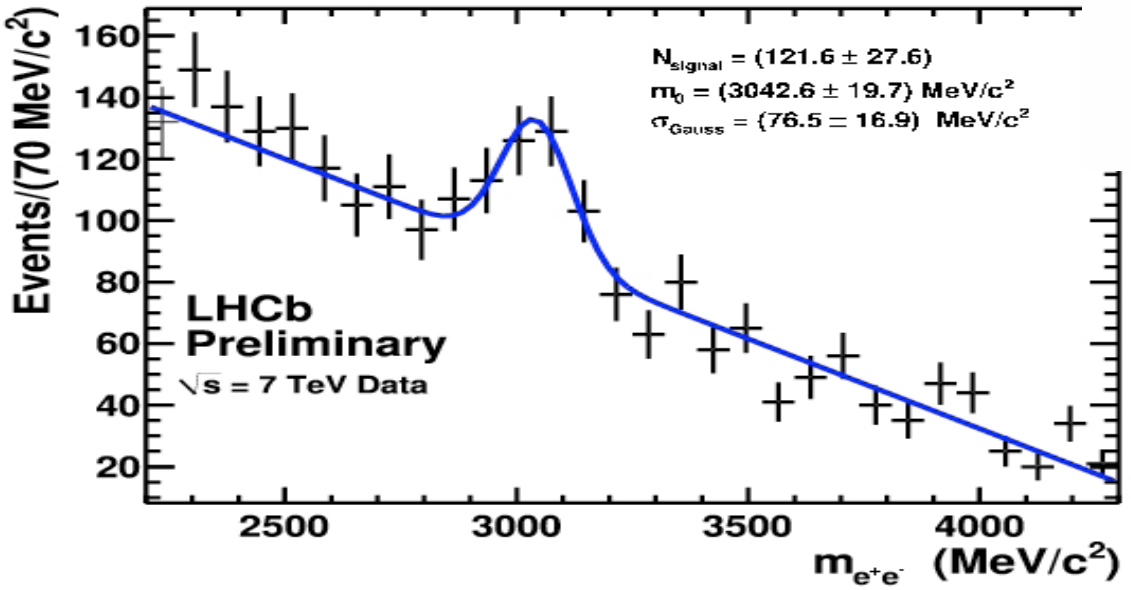




Calorimeters

- Timing already OK at 1 ns level
- Energy calibration improved to 2% level using first π^0 sample
- π^0 resolution (7.2 MeV) even better than expected!
- In the future, improve calibration with electrons from conversions and J/ψ





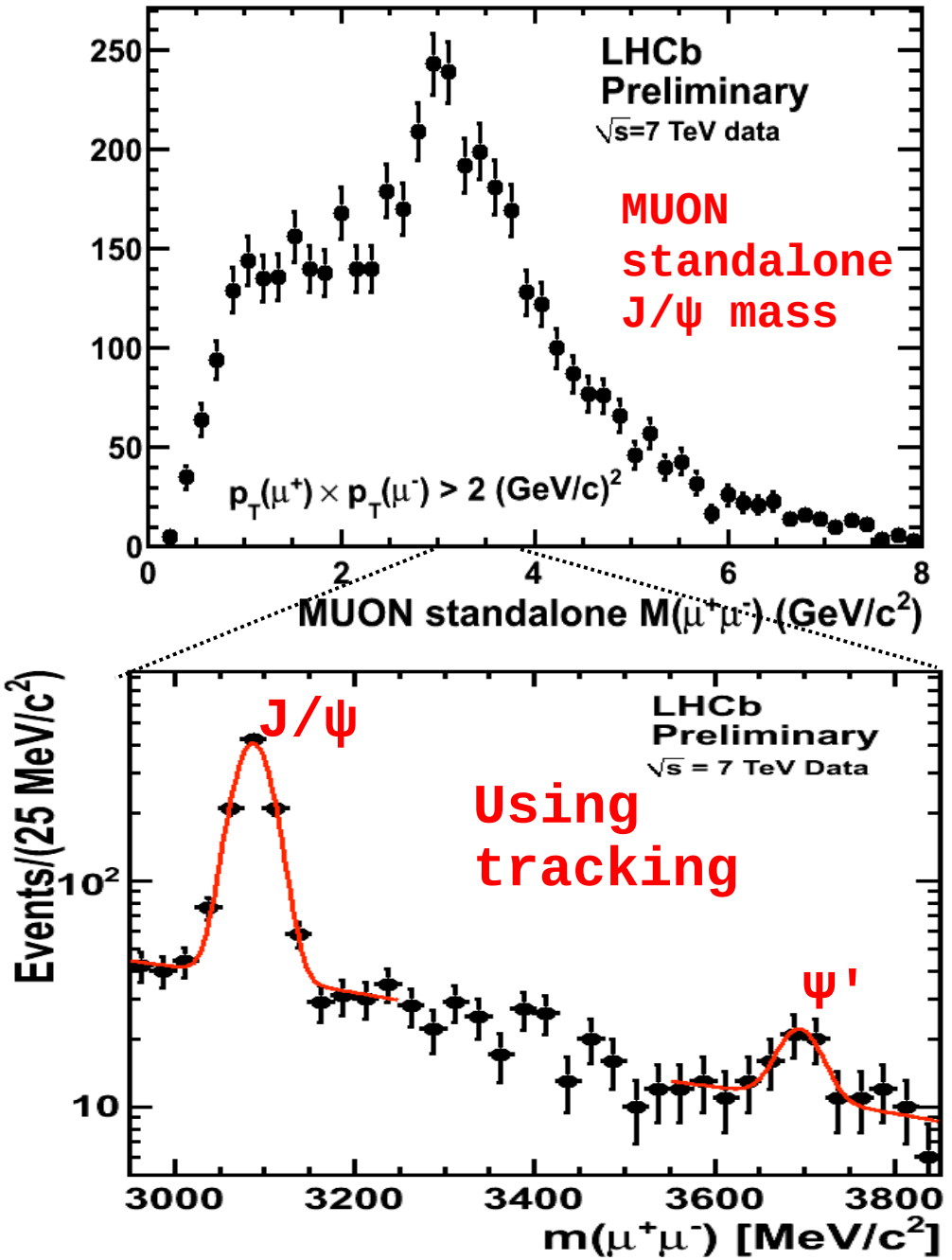
First J/ψ -> e+e- signal

MUON

- Collision data used to refine timing in innermost regions (limited cosmic statistics)
- Reached nominal performances:

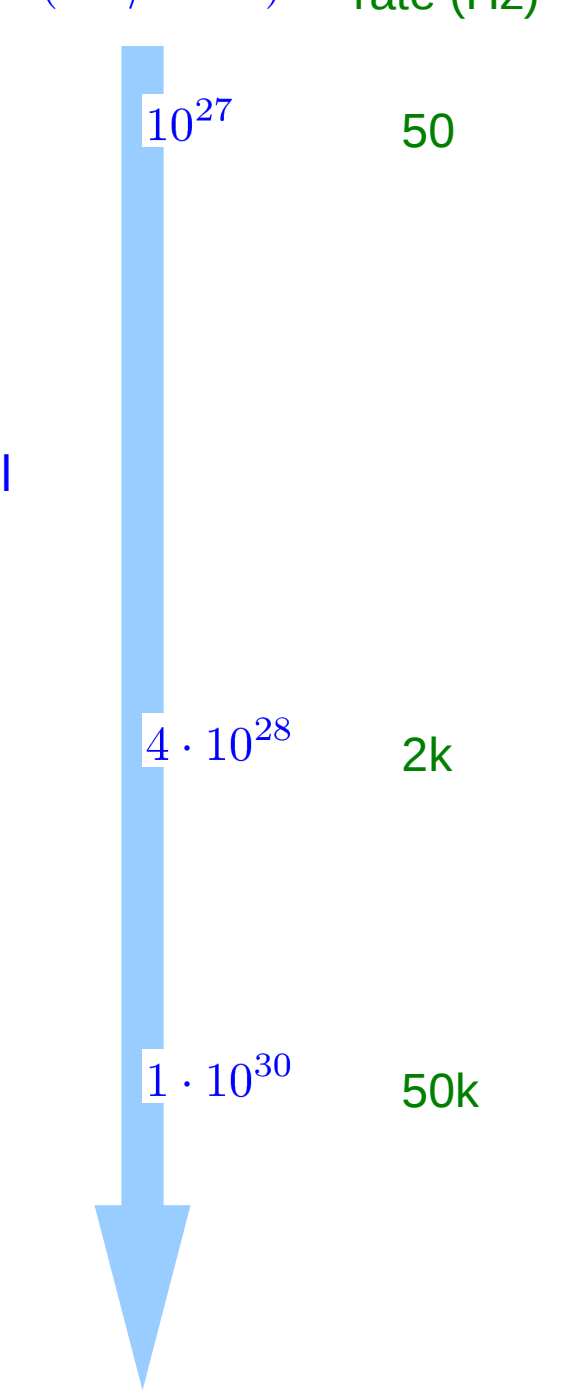
  tracking efficiency in 25 ns (AND of 5 stations)
  > 95 % for p>6 GeV

- Clean J/ψ sample selected
- Muon ID and pion misid performances found in good agreement with simulation



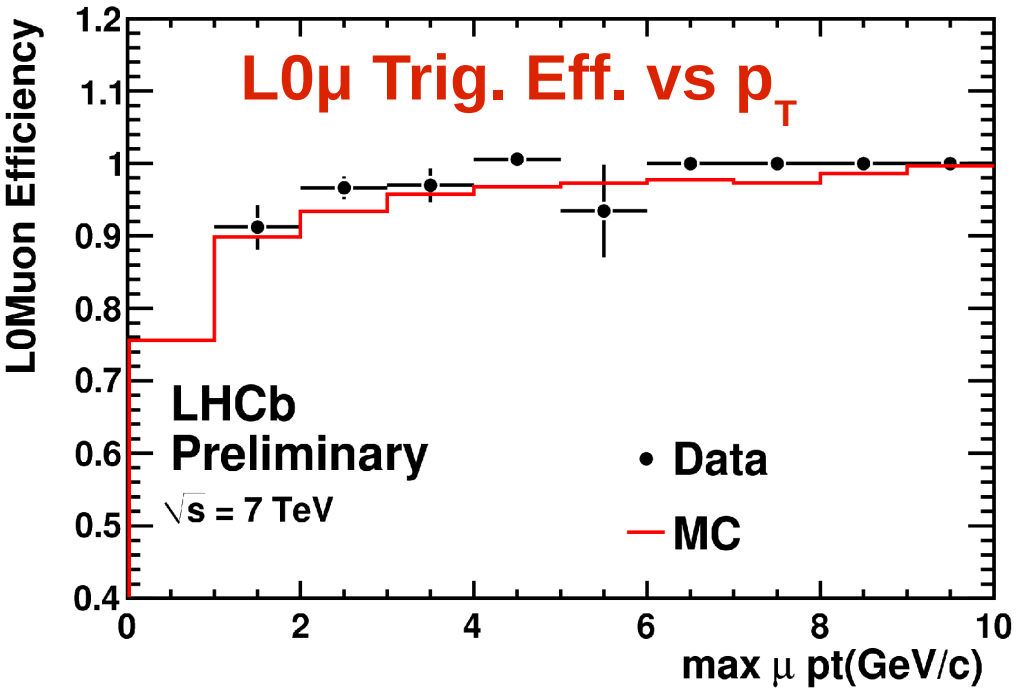
Trigger

- Profit of LHC startup at low luminosity for commissioning and exercising trigger components:
  - Minimum-Bias L0 Trigger (HCAL> 240 MeV && SPD mult.>2, $p_T^{\mu} > 240$ MeV)
  - Micro-Bias trigger (single track, independent on nominal L0)
  - No need for HLT for first 6 weeks (L0 rate < 2 kHz)
- Start HLT1 with relaxed IP cuts, optimize L0 and HLT1 thresholds for charm and beauty. Downscale MB triggers
- Currently running with average number of collisions close to nominal value (0.5 - 1)!



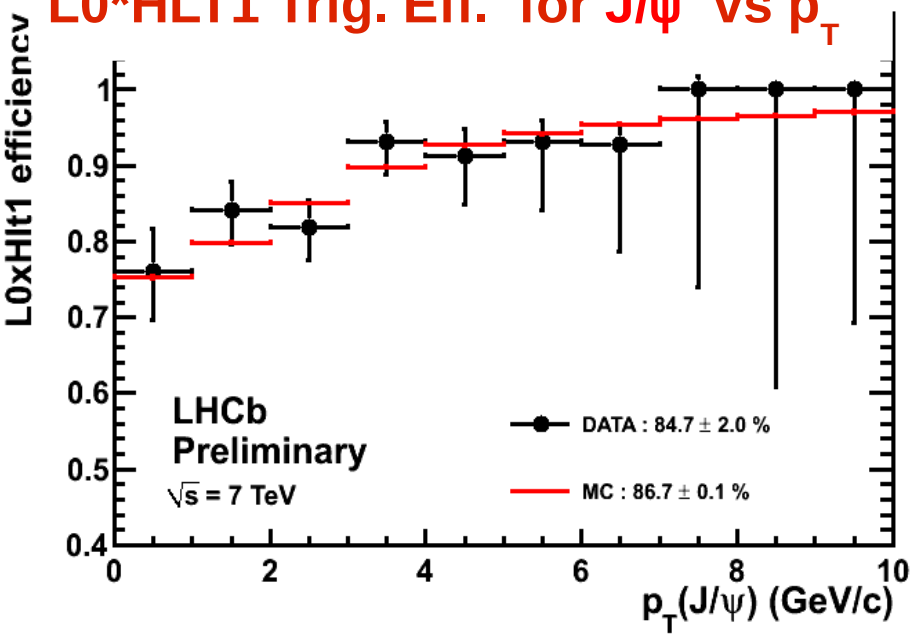
Trigger Performances

- **L0 trigger** efficiency in excellent agreement with simulation
  - L0 μ : 95.5 +/- 1.3 %
  - L0 e : 75.4 +/- 0.6 %



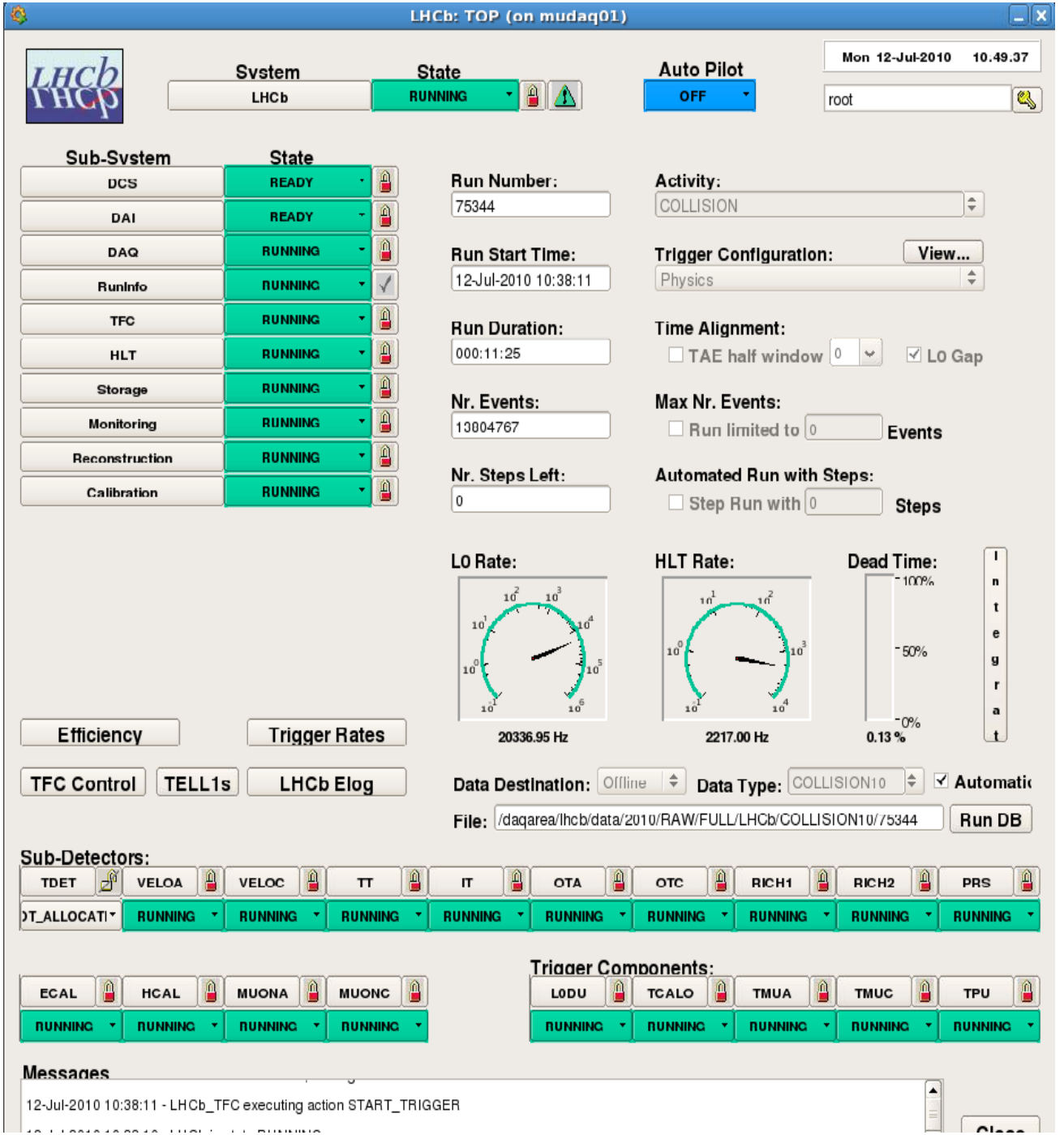
- **L0xHLT1** efficiency measured on J/ψ sample and found in good agreement with expectations:

  first proof of concept of LHCb trigger on real data



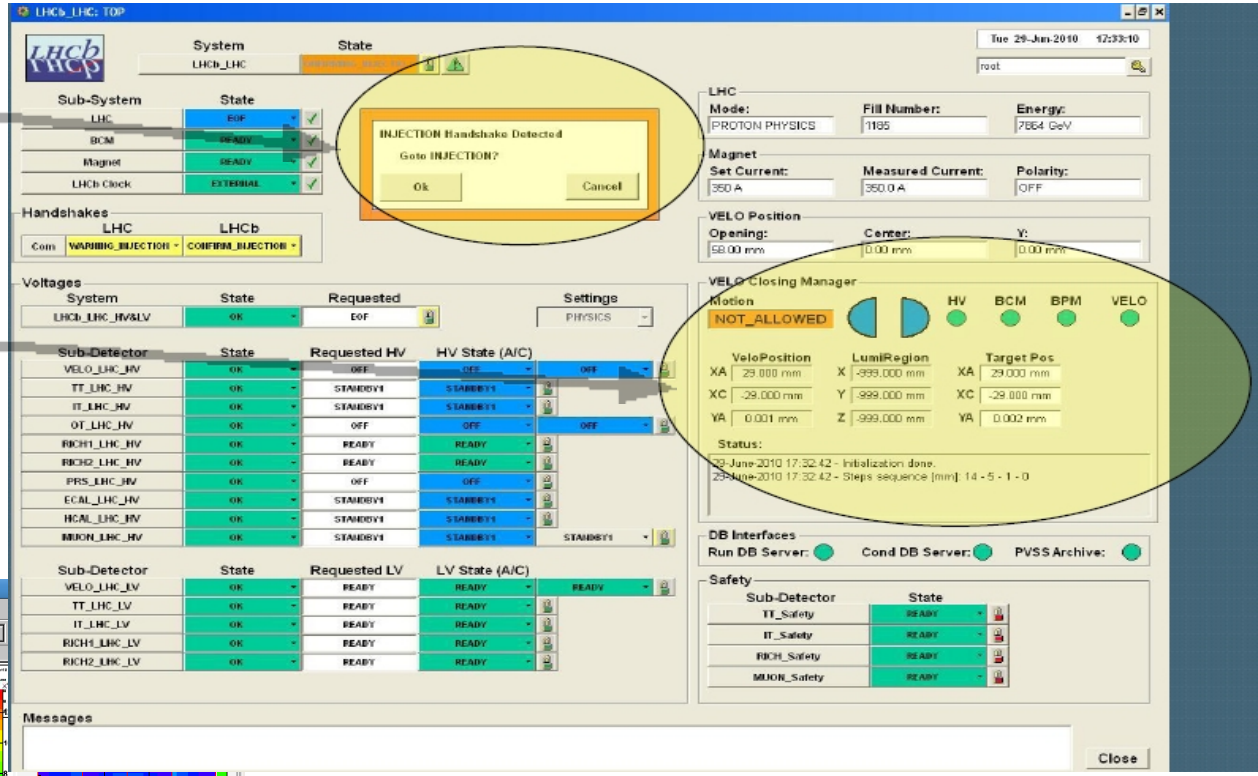
Detector Operation

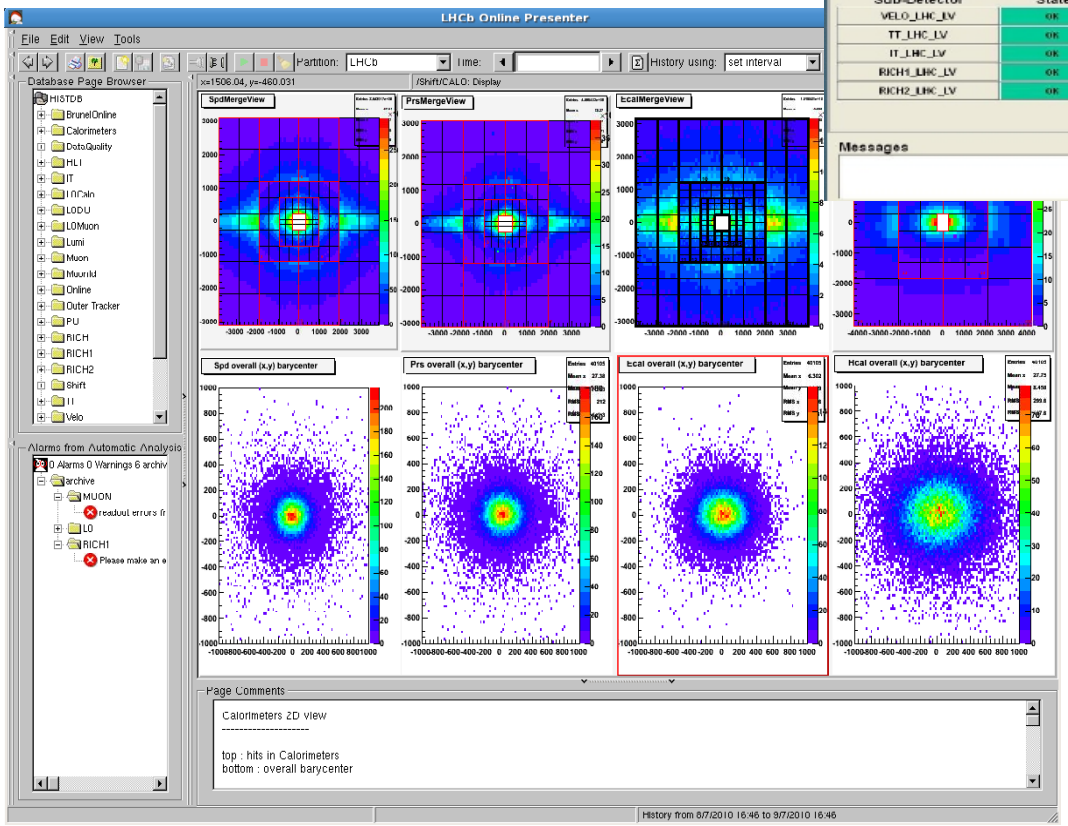
- PVSS based control software allows to run the LHCb detector as a whole from the main console, or to easily run independently detector partitions (crucial to optimize commissioning)



Tools for Operation

- Fully automatized procedure for interaction with LHC (voice assisted)
- VELO closing manager included in the console, though still being operated by detector experts





- Online monitoring framework providing immediate feedback on data quality, including automatic histogram analysis

Smooth Operations...

Conclusions

- The LHCb detector is complete and fully working
- Thanks to the long commissioning phase, alignments and calibrations already close to final on first day of collisions
- Performances with current understanding of the detector allow for first physics results, see following LHCb talks:
  - Luminosity measurement and K_S production (S. Redford)
  - PID performances and baryon/$\overline{\text{baryon}}$ asymmetries (S. Koblitz)
  - Prospects for CP violation measurements (A.Poluektov)
  - Search for rare decays (A. M. Pérez-Calero Yzquierdo)
- Refining alignments to reach nominal vertexing and tracking performances
- Waiting for the “promised” 1/fb from 2010/2011 run (half a nominal LHCb year) for the first results on the LHCb core physics program